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Composite Weak Vector Bosons in a Left-Right Symmetric Preon Model

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We take a view point that the standard model is a low energy effective theory among composite quarks, leptons and weak bosons in a left-right (LR) symmetric preon model with a hyper-color $SU(N)_{HC}$ gauge interaction. Starting from the NJL type of interactions with the global $SU(2)_L \times SU(2)_R$ symmetry, it is constructed the composite weak vector bosons of a pair of spinor preons and derived their effective interactions with quarks and leptons, which are essentially identical, in the tree-diagram level, to those in the LR symmetric gauge model. Through the process of this approach, some physical aspects of the LR gauge model seems to become clear.

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§ 1. Introduction

The success of the standard model (SM) of $SU(3)_c \times SU(2)_L \times U(1)_Y$ gauge symmetry becomes the more remarkable, as the experiments get the higher precision. However, it seems to us that SM is still unsatisfactory theoretically to be truly a fundamental theory. As is well-known, there remain still many problems to be answered : i) The Higgs sector is considered to be somewhat phenomenological and contains too many free parameters. ii) What the physical origin of repetition of three generations is. iii) In SM there exists a maximal left-right asymmetry notwithstanding that quarks and leptons have both left- and right-handed degrees of freedom (note that neutrinos should be massive, at least, to explain the oscillation phenomena).

In this work we shall follow the line of approaches to these problems that SM is a low energy effective theory among composite particles (quarks and leptons, and possibly also weak and Higgs bosons) of preons confined by some fundamental (hypercolor) gauge interaction like QCD. Here, we should like to point out that there is a possibility to answer to all the above problems in this line, although it seems to be an extremely difficult task to find such a realistic model as may pass through the recent high-precision experimental check. On the other hand, in most of more conventional approaches, the super-symmetric generalization of SM, the above problems seem to remain unanswered.

There had been published many pioneering works[1)~10)] in the above line of preon models from the various view points. We shall prefer especially the type of models[11)~13)] with symmetrical left- and right-freedoms, considering the problem iii) seriously. In the previous paper[13)] we had adopted a fermion-boson-type preon model[1),3)] with massive Dirac spinor preons F's, where the weak vector boson's, W_L and W_R, in the respective world of left-hand ($h = L$) and of right-hand ($h = R$) are supposed to be composites of a pair of F_h and $\overline{F}_h$, and investigated phenomenologically a possibility for existence of extra iso-scalar vector bosons.

In this paper we shall further try to develop theoretically a realistic preon model in the same stand-point, by treating dynamically the composition of weak bosons. We shall investigate especially the physical back-ground of left-right (LR) symmetric gauge model[1),14),15)], which are generally accepted as a natural extension of SM in relation to the above mentioned problem iii). For this purpose we shall resort to a solvable model[16)~18)] of the Nambu-Jona-Lasinio type (NJL) adapted for our relevant global symmetry of the confining gauge interaction. The composite model of NJL type with the vector-vector interaction had been proposed[20,21] in the cases of $SU(2)_l$ [7,19,22] or of $SU(N)$ but without referring to LR symmetry.

§ 2.Basic set up of preon model

2A). Preons and Composites

In the previous paper[13], we have presented a model scheme for quarks and leptons as bound states of two kinds of Dirac spinor preon (F^u, F^d) and of four kinds of scalar preon ($C^{(i)}$, $S^{(i)}$) carrying the generation number ($i = 1,2,3$). These preons have the fundamental local gauge interaction, which is symmetric under the group $G_{loc.} \equiv SU(N)_{HC} \times SU(3)_C \times U(1)_{em}$, and are supposed to belong to the representation as shown in Table Ⅰ.

Table Ⅰ

The preons are also supposed to belong to the representations of the group $G_{gl.} \equiv SU(2)_L \times SU(2)_R \times U(1)_B \times U(1)_L$ of the global symmetry as shown in Table Ⅱ.

Table Ⅱ

Then the electric charge is given by the LR-symmetric formula, giving a clear physical meaning to the hyper-charge as

$$Q = I_L^3 + I_R^3 + \frac{B-L}{2} \quad , \qquad (2.1a)$$

$$\frac{Y}{2} \equiv I_R^3 + \frac{B-L}{2} \quad , \qquad (2.1b)$$

where $I^3_{L(R)}$ is the 3rd component of weak iso-spin $SU(2)_{L(R)}$ and $B(L)$ is the baryon(lepton) number. Here it may be worthwhile to note that only the scalar preons are responsible to B and L.

The quarks and leptons are the hyper-color singlet composite states with the preon configurations as, respectively,

$$\begin{pmatrix} u \\ d \end{pmatrix} = \begin{pmatrix} F^u\overline{C}^{(1)} \\ F^d\overline{C}^{(1)} \end{pmatrix} , \quad \begin{pmatrix} c \\ s \end{pmatrix} = \begin{pmatrix} F^u\overline{C}^{(2)} \\ F^d\overline{C}^{(2)} \end{pmatrix} , \quad \begin{pmatrix} t \\ b \end{pmatrix} = \begin{pmatrix} F^u\overline{C}^{(3)} \\ F^d\overline{C}^{(3)} \end{pmatrix} , \tag{2.2 a}$$

and

$$\begin{pmatrix} \nu_e \\ e^- \end{pmatrix} = \begin{pmatrix} F^u\overline{S}^{(1)} \\ F^d\overline{S}^{(1)} \end{pmatrix} , \quad \begin{pmatrix} \nu_\mu \\ \mu \end{pmatrix} = \begin{pmatrix} F^u\overline{S}^{(2)} \\ F^d\overline{S}^{(2)} \end{pmatrix} , \quad \begin{pmatrix} \nu_\tau \\ \tau^- \end{pmatrix} = \begin{pmatrix} F^u\overline{S}^{(3)} \\ F^d\overline{S}^{(3)} \end{pmatrix} . \tag{2.2 b}$$

The weak vector bosons are built from a pair of spinor preons ψ and $\overline{\psi}$ as

$$I_L = 1 ;\ \vec{W}_{L\mu} \approx \overline{\psi}_L \vec{\tau} \gamma_\mu \psi_L , \quad I_L = 0 ;\ W^0_{L\mu} \approx \overline{\psi}_L \gamma_\mu \psi_L \tag{2.3 a}$$

and

$$I_R = 1 ;\ \vec{W}_{R\mu} \approx \overline{\psi}_R \vec{\tau} \gamma_\mu \psi_R , \quad I_R = 0 ;\ W^0_{R\mu} \approx \overline{\psi}_R \gamma_\mu \psi_R , \tag{2.3 b}$$

where

$$\psi \equiv \begin{pmatrix} F^u \\ F^d \end{pmatrix} . \tag{2.4}$$

Here it is to be noted that in our model the extra weak bosons (iso-vector $\vec{W}_R$ and iso-scalar W_L^0 and W_R^0), in addition to the usual iso-vector ones $\vec{W}_L$ are naturally expected to exist. We have investigated the lower limit of the mass of iso-scalar W_L^0 permitted from the low energy experiments in the previous paper[13].

2B). Fundamental gauge interactions for preon system

Thus the Lagrangian density for our fundamental local $G_{loc.}$-gauge interactions is given as

$$\begin{aligned} L = & -\frac{1}{4} F^0_{\mu\nu} F^{0,\mu\nu} - \frac{1}{4} g^a_{\mu\nu} g^{a,\mu\nu} - \frac{1}{4} G^\alpha_{\mu\nu} G^{\alpha,\mu\nu} \\ & + \overline{\psi} i\gamma^\mu \left(\partial_\mu + ie\frac{\tau^3}{2} A^0_\mu + ig_{HC}\frac{\lambda^\alpha}{2} G^\alpha_\mu \right) \psi \\ & + \left| \left(\partial_\mu - e\frac{1}{6} A^0_\mu - g_s \frac{\lambda^a}{2} g^a_\mu - g_{HC}\frac{\lambda^\alpha}{2} G^\alpha_\mu \right) C^{(i)} \right|^2 \\ & + \left| \left(\partial_\mu + e\frac{1}{2} A^0_\mu - g_{HC}\frac{\lambda^\alpha}{2} G^\alpha_\mu \right) S^{(i)} \right|^2 , \end{aligned} \tag{2.5}$$

where the electromagnetic $U(1)_{em}$, the color $SU(3)_C$ and the hypercolor $SU(N)_{HC}$ field strength are defined , respectively, from their vector fields as

$$F^0_{\mu\nu} = \partial_\mu A^0_\nu - \partial_\nu A^0_\mu \tag{2.6a}$$

$$g^a_{\mu\nu} = \partial_\mu g^a_\nu - \partial_\nu g^a_\mu + g_c f^{abc} g^b_\mu g^c_\nu \tag{2.6b}$$

and

$$G^\alpha_{\mu\nu} = \partial_\mu G^\alpha_\nu - \partial_\nu G^\alpha_\mu + g_{HC} f^{\alpha\beta\gamma} G^\beta_\mu G^\gamma_\nu \tag{2.6c}$$

Here it is to be noted that this L , Eq.(2.5), has a symmetry under $G_{gl.}$, especially under the global chiral $SU(2)_L \times SU(2)_R$ transformation.

§ 3. Derivation of effective interactions among composite quarks, leptons and weak bosons

3A). NJL type effective interactions

In this section we shall construct the effective interactions among composite quarks, leptons and weak vector bosons, supposing the situation that our relevant experimental energy $\sqrt{s}$ is in the region far below the composite scale Λ_{cs} as

$$\sqrt{s} << \Lambda_{cs} \tag{3.1}$$

For this purpose, we start from the solvable NJL type interactions of spinor preons with our relevant global symmetry G_{gl} of the fundamental gauge interaction. We consider only the non-differential contact interaction of preons. In this paper we shall focus on composition of the weak vector bosons from a pair of spinor preon and anti-preon, and on derivation of their effective interaction with quarks and leptons.

Thus our relevant Lagrangian density is given by

$$\begin{aligned} L = & \overline{\psi} i\gamma^{\mu}\left(\partial_{\mu} + ie\frac{\tau^3}{2}A^0_{\mu}\right)\psi - m_F\overline{\psi}\psi \\ & -\frac{1}{4}F^0_{\mu\nu}F^{0\mu\nu} \\ & -\frac{G_L}{N_{HC}}\left(\overline{\psi}\gamma_{\mu}\frac{\vec{\tau}}{2}\frac{1-\gamma_5}{2}\psi\right)^2 - \frac{G_R}{N_{HC}}\left(\overline{\psi}\gamma_{\mu}\frac{\vec{\tau}}{2}\frac{1+\gamma_5}{2}\psi\right)^2 \quad ; \end{aligned} \tag{3.2}$$

where m_F is the mass of spinor preons ψ, G_L and G_R are, respectively, the coupling constants among left- and right-handed preons, A^0_{μ} is the $U(1)_{em}$ gauge field, and N_{HC} is the hypercolor number. It has the chiral symmetry of $SU(2)_L \times SU(2)_R$ in the limit $m_F \to 0$. The strong attractive force with positively large coupling constant $G_{L(R)}$ can generate bound states in the spin-one and "hypercolor"-singlet states. We shall attempt to identify them with the " gauge" bosons in the LR gauge model (without Higgs scalar bosons).

3B). Lagrangian of weak bosons interacting with preons

Introducing the auxiliary fields[18] by following the conventional procedure, the Lagrangian density (3.2) is rewritten into the convenient form for our purpose as

$$L' = \bar{\psi} i\gamma^\mu \left(\partial_\mu + ie\frac{\tau^3}{2}A^0_\mu + i\vec{\tau}\cdot\vec{W}_{L\mu}\frac{1-\gamma_5}{2} + i\vec{\tau}\cdot\vec{W}_{R\mu}\frac{1+\gamma_5}{2}\right)\psi - m_F\bar{\psi}\psi$$
$$-\frac{1}{4}F^0_{\mu\nu}F^{0\mu\nu} + \frac{N_{HC}}{G_L}\vec{W}_{L\mu}\cdot\vec{W}^\mu_L + \frac{N_{HC}}{G_R}\vec{W}_{R\mu}\cdot\vec{W}^\mu_R \quad , \tag{3.3}$$

where $\vec{W}_{L\mu}\left(\vec{W}_{R\mu}\right)$ is an auxiliary fields corresponding to the "left-handed(right-handed)" composite weak boson. This Lagrangian has the $SU(2)_L \times SU(2)_R$ local gauge symmetry in the limit of $m_F \to 0$, $G_L \to \infty$ and $G_R \to \infty$.

The next step is to generate the kinetic and interaction terms of the auxiliary fields, $\vec{W}_L$ and $\vec{W}_R$, through the quantum effects of spinor preons corresponding to the loop diagrams in Fig.1.

Fig 1

We consider the two cases of regularization methods for the loop integral, [type I] the usual straight cut(including the quadratic divergence) and [type II] the dimensional regularization(retaining only the logarithmic divergence). The difference between type I and type II appears only in the mass terms of the composite weak bosons. The details of calculations are given in Appendix A. The result is to add to the Lagrangian (3.3) the following terms:

$$\Delta L' = -\frac{1}{4}Z_W\vec{W}_{L\mu\nu}\cdot\vec{W}^{\mu\nu}_L + \frac{3}{2}m_F^2 Z_W\vec{W}_{L\mu}\cdot\vec{W}^\mu_L$$
$$-\frac{1}{4}Z_W\vec{W}_{R\mu\nu}\cdot\vec{W}^{\mu\nu}_R + \frac{3}{2}m_F^2 Z_W\vec{W}_{R\mu}\cdot\vec{W}^\mu_R$$
$$-\frac{3}{2}m_F^2\left(\vec{W}_{L\mu}\cdot\vec{W}^\mu_R + \vec{W}_{R\mu}\cdot\vec{W}^\mu_L\right)$$
$$-\frac{1}{2}\lambda_L\sqrt{Z_W}W^3_{L\mu\nu}F^{0\mu\nu} - \frac{1}{2}\lambda_R\sqrt{Z_W}W^3_{R\mu\nu}F^{0\mu\nu}$$
$$+\frac{e}{2}\varepsilon_{3ij}Z_W F^0_{\mu\nu}W^{i\mu}_L W^{j\nu}_L + \frac{e}{2}\varepsilon_{3ij}Z_W F^0_{\mu\nu}W^{i\mu}_R W^{j\nu}_R \quad , \tag{3.4}$$

where

$$\vec{W}_{L\mu\nu} = \partial_\mu\vec{W}_{L\nu} - \partial_\nu\vec{W}_{L\mu} - g\vec{W}_{L\mu}\times\vec{W}_{L\nu} \quad , \tag{3.5a}$$
$$\vec{W}_{R\mu\nu} = \partial_\mu\vec{W}_{R\nu} - \partial_\nu\vec{W}_{R\mu} - g\vec{W}_{R\mu}\times\vec{W}_{R\nu} \quad . \tag{3.5b}$$

The constant Z_W is given by

$$Z_W = \frac{N_{HC}}{12\pi}\ln\frac{\Lambda^2}{m_F^2} \quad , \tag{3.6}$$

where Λ is the cutoff of the preon loop integrals. In order to make the kinetic terms in Eq.(3.4) have the proper normalization we rescale the boson fields as

$$\vec{W}_{L\mu} = \sqrt{Z_W}\,\tilde{\vec{W}}_{L\mu} \qquad , \tag{3.7a}$$

$$\vec{W}_{R\mu} = \sqrt{Z_W}\,\tilde{\vec{W}}_{R\mu} \qquad . \tag{3.7b}$$

Consequently we get, after adding $\Delta L'(3.4)$ to $L'(3.3)$ and rescaling(3.7), the effective Lagrangian L_{eff} for the system of spinor preons and the composite vector bosons interacting with $U(1)_{em}$ field:

$$\begin{aligned}
L_{eff} =& \overline{\psi}\, i\gamma^{\mu} D_{\mu}\psi - m_F\overline{\psi}\psi \\
&-\frac{1}{4}F^{0}_{\mu\nu}F^{0\mu\nu} \\
&-\frac{1}{4}\vec{W}_{L\mu\nu}\cdot\vec{W}_L^{\mu\nu} + \frac{1}{2}M_L^2\vec{W}_{L\mu}\cdot\vec{W}_L^{\mu} \\
&-\frac{1}{4}\vec{W}_{R\mu\nu}\cdot\vec{W}_R^{\mu\nu} + \frac{1}{2}M_R^2\vec{W}_{R\mu}\cdot\vec{W}_R^{\mu} \\
&-\frac{3}{2}m_F^2\left(\vec{W}_{L\mu}\cdot\vec{W}_R^{\mu} + \vec{W}_{R\mu}\cdot\vec{W}_L^{\mu}\right) \\
&-\frac{1}{2}\frac{e}{g}F^{0}_{\mu\nu}\left(\partial^{\mu}W_L^{3\nu} - \partial^{\nu}W_L^{3\mu}\right) - \frac{1}{2}\frac{e}{g}F^{0}_{\mu\nu}\left(\partial^{\mu}W_R^{3\nu} - \partial^{\nu}W_R^{3\mu}\right) \qquad ,
\end{aligned} \tag{3.8}$$

where the covariant derivative D_{μ} is defined by

$$D_{\mu} = \partial_{\mu} + ie\frac{\tau^3}{2}A^{0}_{\mu} + ig\frac{\vec{\tau}}{2}\cdot\vec{W}_{L\mu}\frac{1-\gamma_5}{2} + ig\frac{\vec{\tau}}{2}\cdot\vec{W}_{R\mu}\frac{1+\gamma_5}{2} \qquad ; \tag{3.9}$$

and the "gauge" coupling constants of left-handed and of right-handed weak bosons g_L and g_R, respectively, are given by a common formula

$$g_L = g_R = g = \frac{1}{\sqrt{\dfrac{N_{HC}}{48\pi^2}\ln\dfrac{\Lambda^2}{m_F^2}}} \tag{3.10}$$

independently of G_L and G_R. The masses of W_L and W_R are given, respectively, in each case of regularization as

[type Ⅰ]:

$$M_L^2 = \frac{2N_{HC}}{G_L Z_W} - \frac{N_{HC}}{8\pi^2}Z_W\Lambda^2 + 3m_F^2 \qquad , \tag{3.11a}$$

$$M_R^2 = \frac{2N_{HC}}{G_R Z_W} - \frac{N_{HC}}{8\pi^2}Z_W\Lambda^2 + 3m_F^2 \qquad , \tag{3.11b}$$

[type Ⅱ]:

$$M_L^2 = \frac{2N_{HC}}{G_L Z_W} + 3m_F^2 \qquad , \tag{3.12a}$$

$$M_R^2 = \frac{2N_{HC}}{G_R Z_W} + 3m_F^2 \qquad . \tag{3.12b}$$

It is interesting that the mixing parameters between A^0_{μ} and $W^3_{L\mu}\left(W^3_{R\mu}\right)$ are given also commonly as

$$\lambda_L = \frac{e}{g} , \qquad \lambda_R = \frac{e}{g} . \qquad (3.13)$$

The first relation, so called the unification condition[23),25)], had been required in the current mixing scheme[23~25)] between A_μ^0 and $W_{L\mu}^3$, while derived in the NJL type subquark model[22)] (only with global $SU(2)_L$ symmetry), in order to derive the similar neutral current interactions as SM at the low-energy, as will be shown later. In the LR gauge model[15)] inspired by preon model relation (3.13) had also been supposed. In deriving Eq.(3.8), following the conventional procedure, we kept only the most divergent terms, taking the limit of infinite Λ , when the finite term becomes zero. It is to be noted that in Eq.(3.8), the preon loop diagrams generate necessarily the current mixing terms between A_μ^0 and W_μ's, which were supposed in the previous works [13)]; and, in addition, the mass mixing terms between $W_{L\mu}$ and $W_{R\mu}$.

3C). Lagrangian of weak bosons interacting with composite quarks and leptons

By attaching the "spectator" scalar preons to the spinor preons (as is seen in Fig.2),

Fig 2

we may simply regard Eq.(3.8) as the Lagrangian of weak bosons interacting with the composite quarks and leptons. Since we are supposing the physical situation of Eq.(3.1), this attaching process seems not to produce any physical effects such as the form factor effects. Thus we obtain our relevant effective Lagrangian for the composite quark, lepton and weak boson system as;

$$
\begin{aligned}
L_{eff} = & \sum_{i=1}^{3} \overline{\psi}_i \left(i\gamma^\mu \partial_\mu - m_i \right) \psi_i \\
& - \frac{g}{\sqrt{2}} \sum_{i=1}^{3} \left(\overline{\psi}_{i,L}^U \gamma^\mu \psi_{i,L}^D W_{L\mu}^+ + \overline{\psi}_{i,L}^D \gamma^\mu \psi_{i,L}^U W_{L\mu}^- \right) \\
& - \frac{g}{\sqrt{2}} \sum_{i=1}^{3} \left(\overline{\psi}_{i,R}^U \gamma^\mu \psi_{i,R}^D W_{R\mu}^+ + \overline{\psi}_{i,R}^D \gamma^\mu \psi_{i,R}^U W_{R\mu}^- \right) \\
& - \frac{1}{2} W_{L\mu\nu}^+ W_L^{-\mu\nu} + M_L^2 W_{L\mu}^+ W_L^{-\mu} \\
& - \frac{1}{2} W_{R\mu\nu}^+ W_R^{-\mu\nu} + M_R^2 W_{R\mu}^+ W_R^{-\mu} \\
& - 3m_F^2 \left(W_{L\mu}^+ W_R^{-\mu} + W_{R\mu}^+ W_L^{-\mu} \right) \\
& - e \sum_{i=1}^{3} Q_i \overline{\psi}_i \gamma^\mu \psi_i A_\mu^0
\end{aligned}
$$

$$
\begin{aligned}
&-g\sum_{i=1}^{3}\left(\overline{\psi}_{iL}\gamma^{\mu}\frac{\tau^{3}}{2}\psi_{iL}\right)W_{L\mu}^{3}-g\sum_{i=1}^{3}\left(\overline{\psi}_{iR}\gamma^{\mu}\frac{\tau^{3}}{2}\psi_{iR}\right)W_{R\mu}^{3}\\
&-\frac{1}{4}F_{\mu\nu}^{0}F^{0\mu\nu}\\
&-\frac{1}{4}W_{L\mu\nu}^{3}W_{L}^{3\mu\nu}+\frac{1}{2}M_{L}^{2}W_{L\mu}^{3}W_{L}^{3\mu}\\
&-\frac{1}{4}W_{R\mu\nu}^{3}W_{R}^{3\mu\nu}+\frac{1}{2}M_{R}^{2}W_{R\mu}^{3}W_{R}^{3\mu}\\
&-\frac{3}{2}m_{F}^{2}\left(W_{L\mu}^{3}W_{R}^{3\mu}+W_{R\mu}^{3}W_{L}^{3\mu}\right)\\
&-\frac{1}{2}\frac{e}{g}F_{\mu\nu}^{0}\left(\partial^{\mu}W_{L}^{3\nu}-\partial^{\nu}W_{L}^{3\mu}\right)\\
&-\frac{1}{2}\frac{e}{g}F_{\mu\nu}^{0}\left(\partial^{\mu}W_{R}^{3\nu}-\partial^{\nu}W_{R}^{3\mu}\right)\\
&+i\frac{e}{2}F_{\mu\nu}^{0}\left(W_{L}^{-\mu}W_{L}^{+\nu}-W_{L}^{+\mu}W_{L}^{-\nu}\right)\\
&+i\frac{e}{2}F_{\mu\nu}^{0}\left(W_{R}^{-\mu}W_{R}^{+\nu}-W_{R}^{+\mu}W_{R}^{-\nu}\right) \qquad , \qquad (3.14)
\end{aligned}
$$

where m_i's are the masses of i-th generation quarks and leptons generated by hands. Here the quantities are defined as follows: $W_{L\mu}^{\pm}=\frac{1}{\sqrt{2}}\left(W_{L\mu}^{1}\mp iW_{L\mu}^{2}\right)$ and $W_{R\mu}^{\pm}=\frac{1}{\sqrt{2}}\left(W_{R\mu}^{1}\mp iW_{R\mu}^{2}\right)$, $\psi_{iL}\equiv\left(\psi_{iL}^{U},\psi_{iL}^{D}\right)^{T}$ $\left[\left(\nu_{iL},l_{iL}^{-}\right)^{T}\text{ or }\left(u_{iL},d_{iL}'\right)^{T}\right]$ is the $SU(2)_L$ doublet of left-handed fermion fields of the i-th family, and similarly $\psi_{iR}\equiv\left(\psi_{iR}^{U},\psi_{iR}^{D}\right)^{T}$ $\left[\left(\nu_{iR},l_{iR}^{-}\right)^{T}\text{ or }\left(u_{iR},d_{iR}'\right)^{T}\right]$ is the $SU(2)_R$ doublet of right-handed fermion fields, where $d_{iL}'\equiv\sum_j V_{ij}^{L}d_{iL}$ and $d_{iR}'\equiv\sum_j V_{ij}^{R}d_{iR}$. The V^L is the Cabibbo-Kobayashi-Maskawa(CKM) mixing matrix. The V^R is a similar mixing matrix concerning the right-handed world. This matrix V^R is in our model identical to V^L, since the mixing mechanism is determined through the scalar preons having the generation number; while it is, in principle, independent of V^L in the LR gauge model. Here it is to be noted that in our model the mixing matrix of the leptons is also existing within our concern.

3D). Low-energy effective Lagrangian for composite quarks, leptons and weak bosons

The Lagrangian (3.14) contains the off-diagonal mixing terms being bilinear in boson fields. We shall rewrite it in terms of the physical boson fields with the diagonal mass-matrices. The physical boson fields are obtained by the transformation as

$$
\begin{pmatrix} W_{\mu}^{\pm} \\ W_{\mu}'^{\pm} \end{pmatrix}=\begin{pmatrix} \cos\varsigma & \sin\varsigma \\ -\sin\varsigma & \cos\varsigma \end{pmatrix}\begin{pmatrix} W_{L\mu}^{\pm} \\ W_{R\mu}^{\pm} \end{pmatrix} \qquad , \qquad (3.15a)
$$

and

$$\begin{pmatrix} A'_\mu \\ Z_\mu \\ Z'_\mu \end{pmatrix} = \begin{pmatrix} 1 & \frac{e}{g} & \frac{e}{g} \\ 0 & -\sqrt{1-(e/g)^2} & \frac{(e/g)^2}{\sqrt{1-(e/g)^2}} \\ 0 & 0 & \sqrt{\frac{1-2(e/g)^2}{1-(e/g)^2}} \end{pmatrix} \begin{pmatrix} A^0_\mu \\ W^3_{L\mu} \\ W^3_{R\mu} \end{pmatrix} \quad , \tag{3.15b}$$

with ς defined by

$$\tan 2\varsigma = \frac{12 m_F^2}{g^2 N_{HC}} \frac{1}{\frac{1}{G_L} - \frac{1}{G_R}} \tag{3.15c}$$

, where we have neglected the quantities of order $O\left(\frac{M_L^2}{M_R^2}, \frac{m_F^2}{M_R^2}\right)$ (As for them see the Appencix B) . Here A_μ, $W_\mu^\pm$, Z_μ, $W_\mu'^\pm$ and Z'_μ denote, respectively, the physical photon, the physical charged weak bosons, the physical particles of neutral weak boson, extra charged weak boson, and extra neutral weak boson.

The charged quark or lepton current are defined by

$$J^-_{L\mu} = \sum_i \left(\overline{\psi}^U_{iL} \gamma_\mu \psi^D_{iL}\right) \quad , \quad J^+_{L\mu} = \sum_i \left(\overline{\psi}^D_{iL} \gamma_\mu \psi^U_{iL}\right) \quad , \tag{3.16a}$$

and

$$J^-_{R\mu} = \sum_i \left(\overline{\psi}^U_{iR} \gamma_\mu \psi^D_{iR}\right) \quad , \quad J^+_{R\mu} = \sum_i \left(\overline{\psi}^D_{iR} \gamma_\mu \psi^U_{iR}\right) \quad . \tag{3.16b}$$

In a similar way, the electromagnetic and the neutral quark or lepton current are defined by

$$J^{em}_\mu = \sum_i \overline{\psi}_i \gamma_\mu \psi_i \quad , \tag{3.17a}$$

and

$$J^3_{L\mu} = \sum_i \left(\overline{\psi}_{iL} \gamma_\mu \frac{\tau^3}{2} \psi_{iL} \right) \quad , \quad J^3_{R\mu} = \sum_i \left(\overline{\psi}_{iR} \gamma_\mu \frac{\tau^3}{2} \psi_{iR} \right) \quad . \tag{3.17b}$$

In the following, we shall omit the trilinear and quadrilinear terms in boson fields. Then our relevant effective Lagrangian is given by

$$\begin{aligned} L^P_{eff} = & \sum_{i=1}^{3} \overline{\psi}_i \left(i\gamma^\mu \partial_\mu - m_F\right)\psi_i \\ & -\frac{1}{2} W^+_{\mu\nu} W^{-\mu\nu} + M_W^2 W^+_\mu W^{-\mu} \\ & -\frac{g}{\sqrt{2}}\left(J_L^{-\mu}\cos\varsigma + J_R^{-\mu}\sin\varsigma\right)W^+_\mu - \frac{g}{\sqrt{2}}\left(J_L^{+\mu}\cos\varsigma + J_R^{+\mu}\sin\varsigma\right)W^-_\mu \\ & -\frac{1}{2} W'^+_{\mu\nu} W'^{-\mu\nu} + M_{W'}^2 W'^+_\mu W'^{-\mu} \\ & -\frac{g}{\sqrt{2}}\left(-J_L^{-\mu}\sin\varsigma + J_R^{-\mu}\cos\varsigma\right)W'^+_\mu - \frac{g}{\sqrt{2}}\left(-J_L^{+\mu}\sin\varsigma + J_R^{+\mu}\cos\varsigma\right)W'^-_\mu \\ & -\frac{1}{4} F_{\mu\nu} F^{\mu\nu} - eA^\mu J^{em}_\mu \\ & -\frac{1}{4} Z_{\mu\nu} Z^{\mu\nu} + \frac{1}{2} M_Z^2 Z_\mu Z^\mu \end{aligned}$$

$$-\frac{e}{\sin\theta_W\cos\theta_W}\left(J^3_{L\mu}-\sin^2\theta_W J^{em}_\mu\right)Z^\mu$$
$$-\frac{1}{4}Z'_{\mu\nu}Z'^{\mu\nu}+\frac{1}{2}M^2_{Z'}Z'_\mu Z'^\mu$$
$$-\frac{e}{\sqrt{\cos 2\theta_W}\sin\theta_W\cos\theta_W}\left(\cos^2\theta_W J^3_{R\mu}+\sin^2\theta_W J^3_{L\mu}-\sin^2\theta_W J^{em}_\mu\right)Z'^\mu \quad , \tag{3.18}$$

where

$$W^+_{\mu\nu}\equiv\partial_\mu W^+_\nu-\partial_\nu W^+_\mu \quad , \tag{3.19a}$$
$$W'^+_{\mu\nu}\equiv\partial_\mu W'^+_\nu-\partial_\nu W'^+_\mu \quad , \tag{3.19b}$$
$$Z_{\mu\nu}\equiv\partial_\mu Z_\nu-\partial_\nu Z_\mu \quad , \tag{3.19c}$$
$$Z'_{\mu\nu}\equiv\partial_\mu Z'_\nu-\partial_\nu Z'_\mu \quad . \tag{3.19d}$$
$$F_{\mu\nu}\equiv\partial_\mu A_\nu-\partial_\nu A_\mu \quad . \tag{3.19e}$$
$$M^2_W=M^2_L-3m^2_F\tan 2\varsigma \quad , \tag{3.20a}$$
$$M^2_{W'}=M^2_R+3m^2_F\tan 2\varsigma \quad , \tag{3.20b}$$
$$M^2_Z=\frac{1}{1-\sin^2\theta_W}M^2_L \quad , \tag{3.20c}$$
$$M^2_{Z'}=\frac{\cos^2\theta_W}{1-2\sin^2\theta_W}M^2_R \quad . \tag{3.20d}$$

and $\sin\theta_W\equiv e/g$ is the weak angle Our Lagrangian (3.18) has essentially the similar structure as that of the LR gauge model without the Higgs bosons at the tree level. It is to be noted that although the charged sector is exactly the same as the LR symmetric model[1,14,15,26)], the neutral sector is only approximately identical. In the limit $M'_W(M'_Z)\rightarrow\infty$, this Lagrangian is identical to that in the electroweak gauge sector of the SM.

§ 4. Concluding remarks

First we summarize our results: In this paper we take the standpoint that the SM is a low energy effective theory among composite quarks, leptons and weak bosons in a LR symmetric preon model with a hyper-color $SU(N)_{HC}$ gauge interaction. Starting from the NJL type of interactions of massive Dirac preons (mass, m_F) with global $SU(2)_L\times SU(2)_R$ symmetry, we have constructed the composite weak vector-bosons of a pair of spinor preons, and derived their effective interactions with quarks or leptons. The main results are as follows:

i) The respective coupling constants $g_L(g_R)$ of our "gauge-bosons" $W_L(W_R)$ in the left-(right-) handed worlds become equal, $g_L = g_R$, regardless of the values of NJL-coupling constants. ii) The masses of $W_L(W_R)$ become zero[22] in the strong coupling limit $G_L(G_R) \to \infty$, and the effective interactions realize the local $SU(2)_L$ $(SU(2)_R)$ gauge symmetry, when applying the dimensional regularization for loop-integrals. iii) The mixing of our neutral W bosons with photons becomes of the current-current type and the unification condition (3.13), $\lambda_L = \lambda_R = e/g$, on the "gauge" coupling constant $g_L(g_R)$ and e is necessarily derived. Accordingly, as is well-known, our effective interactions become identical to the one of LR gauge model in the tree-diagram level. iv) The KM-mixing matrices of charged currents become equal trivially between the left- and right- handed worlds.

Secondly we give an estimate of our model parameters, Λ and N_{HC}, to have any image on the preon world. Supposing the case of $M_{W'}$ and $M_{Z'}$ becoming infinite (, which corresponds to the weak coupling limit $G_R \to 0$ in the right handed world), our effective interactions Eq.(3.18) become identical to those of SM in the case of massive W bosons without Higgs particles. Our model in this limit coincides with that of Ref. 22). Furthermore, taking the strong coupling limit $G_L \to \infty$ (, when $M_W = M_Z \Rightarrow 0$ with $m_F = 0$ and with the type II of dimensional regularization) in Eq.(3.20a), we are led to a maximal value of preon-mass $m_F^{\max}$

$$m_F^{\max} = \frac{1}{\sqrt{3}} M_W = 46 \text{ GeV} \quad , \tag{4.1}$$

with the experimental value of $M_W = 80.22(\pm 0.26)$ GeV. Concerning the number of hyper-color dimension, it is derived from Eq.(3.12) and (3.13) the relation

$$N_{HC} = \frac{6\pi \sin^2\theta_W}{\alpha \ln(\Lambda / m_F)} \quad . \tag{4.2}$$

In Table 3 we have given the values of Λ for tentative values of $m_F = 46$ GeV $(m_F^{\max})$ and 1 GeV, which are determined from Eq.(4.2), taking the experimental values[27] of $\sin^2\theta_W = 0.2318(\pm 0.0005)$, and using the value[27] of $\alpha = e^2/4\pi = 1/128$. From this table we see that it is in our model necessary to suppose the large N_{HC}, which may guarantee the $1/N_{HC}$ expansion.

Table 3

Then we consider whether any physical effect, concerning the right-handed world, may be seen or not.

Our tentative value of Λ has an order of ten or more to the ten TeV, which implies that the internal structure of composite W-bosons may not be recognizable presently as was supposed at the beginning in § 1. Accordingly our model, as it is, is effectively a LR-symmetric massive Yang-Mills theory, and our effective Lagrangian Eq.(3.18) is similar to that of the LR-symmetric gauge model in the tree-diagram level: The charged-current sectors in both the cases are identical, and the results of analyses [26] in the latter on the lower limit of $M_{W'}$ (the mass of W') and the upper limit of ς (the LR-mixing parameter) are also applied in our case to lead

$$M_{W'} > 1.4\ TeV \quad , \tag{4.3a}$$

$$\varsigma < 0.003 \quad . \tag{4.3b}$$

Our neutral-current sectors given in Eq.(3.18) are also equivalent to those in the LR-gauge model, where the quantity with an order of M_L^2 / M_R^2 and/or m_F^2 / M_R^2 , has been neglected. The corrections to this order of Lagrangian is described in Appendix B. This change may affect an estimate of the axial vector coupling constant g_A^l in SM. By constraining the effect due to this correction to be within the uncertainty of $g_A^l = 0.5008 \pm 0.0008$ from the LEP and SLC experiments[27], we obtain the lower limit of W' mass as

$$M_{W'} \approx M_R > 3\ TeV \quad . \tag{4.4}$$

(See Appendix B as for the details of this estimation)

Almost the same results are obtained from a similar consideration on the vector coupling.

Finally we mention some prospect of our approach in connection to the recent high-precision experimental check, which may be extremely difficult to pass through for any approaches over SM from the view point of composite model.

A possible way for this may be just to follow the scenario in the LR symmetric gauge model, investigating its physical background from the view point of our preon model. For this purpose it is necessary to treat dynamically the composition of Higgs scalars, required to exist there, and to apply the mechanism of dynamical breaking of the global $SU(2)_L \times SU(2)_R$ symmetry. This is now under investigation, and will be given in a separate paper[28].

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Appendix A

— *Derivation of quantum effects* —

In this appendix we shall derive the divergent parts $\Delta L'$ given in § 3 B, quantum effects of spinor preons, through the loop diagrams (Fig.1). The generating functional of our model Lagrangian is given by

$$Z = \frac{1}{Z_0}\int D\psi D\bar{\psi} D\vec{\tilde{W}}_L^{\mu} D\vec{\tilde{W}}_R^{\mu} DA_\mu \exp i\int d^4x\, L' \quad , \tag{A.1}$$

where Z_0 is the constant of normalization. Carrying out the path-integrals over ψ and $\bar{\psi}$, we get ΔL representing the quantum corrections to the Lagrangian L' , The correction owing to the preon loop diagrams is given by

$$\begin{aligned} &-iN_{HC}\, Tr\left[\ln\left(i\gamma^\mu\partial_\mu - m_F - e\frac{\tau^3}{2}\gamma^\mu A_\mu^0 + \gamma^\mu\vec{\tau}\cdot\vec{W}_{L\mu}\frac{1-\gamma_5}{2} + \gamma^\mu\vec{\tau}\cdot\vec{W}_{R\mu}\frac{1+\gamma_5}{2}\right)\right] \\ &= iN_{HC}\sum_{n=1}^{\infty}\frac{1}{n}\left[\frac{1}{i\gamma^\nu\left(\partial_\nu + ie\frac{\tau^3}{2}A_\nu^0\right) - m_F}\gamma^\mu\left(\vec{\tau}\cdot\vec{W}_\mu^L\frac{1-\gamma_5}{2} + \vec{\tau}\cdot\vec{W}_\mu^R\frac{1+\gamma_5}{2}\right)\right]^n . \end{aligned} \tag{A.2}$$

We expand each term in the right-hand side of Eq.(A.2) in terms of the fields $\vec{W}_{L\mu}$ and $\vec{W}_{R\mu}$. Eq.(A.2) is represented by a sum of Feynman diagrams. We retain only divergent terms. After some trace calculations we have

$$\begin{aligned} \Delta L' = &-\frac{1}{4}Z_W\vec{\tilde{W}}_{L\mu\nu}\cdot\vec{\tilde{W}}_L^{\mu\nu} + \frac{3}{2}m_F^2 Z_W\vec{\tilde{W}}_{L\mu}\cdot\vec{\tilde{W}}_L^{\mu} \\ &-\frac{1}{4}Z_W\vec{\tilde{W}}_{R\mu\nu}\cdot\vec{\tilde{W}}_R^{\mu\nu} + \frac{3}{2}m_F^2 Z_W\vec{\tilde{W}}_{R\mu}\cdot\vec{\tilde{W}}_R^{\mu} \\ &-\frac{3}{2}m_F^2 Z_W\left(\vec{\tilde{W}}_{L\mu}\cdot\vec{\tilde{W}}_R^{\mu} + \vec{\tilde{W}}_{R\mu}\cdot\vec{\tilde{W}}_L^{\mu}\right) \\ &+\frac{1}{2}\frac{e}{g}\sqrt{Z_W}\left(\tilde{W}_{L\mu\nu}^3 F^{0\mu\nu} + \tilde{W}_{R\mu\nu}^3 F^{0\mu\nu}\right) \end{aligned}$$

$$
+\frac{e}{2} Z_W \varepsilon_{3ij}\left(F^0_{\mu\nu}\tilde{W}_L^{i\mu}\tilde{W}_L^{j\nu} + F^0_{\mu\nu}\tilde{W}_R^{i\mu}\tilde{W}_R^{j\nu}\right)
$$

$$
-Z_W \frac{i}{4}\varepsilon^{\rho\mu\sigma\nu}\left[\left(\partial_\rho \vec{\tilde{W}}_{L\mu}\right)\cdot\left(\partial_\sigma \vec{\tilde{W}}_{L\nu}\right) - \left(\partial_\rho \vec{\tilde{W}}_{R\mu}\right)\cdot\left(\partial_\sigma \vec{\tilde{W}}_{R\nu}\right)\right]. \qquad \text{(A.3)}
$$

The last terms is a anomalous surface term in our case.

Appendix B

— *Neutral current Interactions in the order of* M_L^2 / M_R^2 and m_F^2 / M_R^2 —

In this appendix, we shall describe the next order of the neutral current interaction Lagrangian in our model, which was neglected in § 3 D). The physical boson fields are obtained by the transformation as

$$
\begin{pmatrix} A_\mu \\ Z_\mu \\ Z'_\mu \end{pmatrix} = \begin{pmatrix} 1 & \sin\theta_W & \sin\theta_W \\ 0 & -\cos\theta_W + O_{22} & \sin\theta_W \tan\theta_W + O_{23} \\ 0 & O_{32} & \dfrac{\sqrt{\cos 2\theta_W}}{\cos\theta_W} + O_{33} \end{pmatrix} \begin{pmatrix} A^0_\mu \\ W^3_{L\mu} \\ W^3_{R\mu} \end{pmatrix} , \qquad \text{(B.1)}
$$

with O's defined by

$$
O_{22} = -\frac{\cos 2\theta_W \left(1 - 3\sin^2\theta_W + \sin^4\theta_W\right)}{2\cos^5\theta_W}\frac{M_L^2}{M_R^2} , \qquad \text{(B.2a)}
$$

$$
O_{23} = -\frac{\cos 2\theta_W}{2\cos^3\theta_W}\left(\frac{1 - 5\sin^2\theta_W + \sin^4\theta_W}{\cos^2\theta_W}\frac{M_L^2}{M_R^2} + \frac{6m_F^2}{M_R^2}\right) , \qquad \text{(B.2b)}
$$

$$
O_{32} = -\frac{\cos 2\theta_W \left(1 - 3\sin^2\theta_W + \sin^4\theta_W\right)}{2\cos^5\theta_W}\frac{M_L^2}{M_R^2} , \qquad \text{(B.2c)}
$$

$$
O_{33} = -\frac{\tan^2\theta_W \sqrt{\cos 2\theta_W}}{\cos\theta_W}\left(\tan^2\theta_W \frac{M_L^2}{M_R^2} - \frac{3m_F^2}{M_R^2}\right) . \qquad \text{(B.2d)}
$$

The interaction Lagrangian is given as

$$
L_{\text{int}}^{N.C.} = \begin{pmatrix} A_\mu & Z_\mu & Z'_\mu \end{pmatrix} \begin{pmatrix} 1 & 0 & 0 \\ \tan\theta_W + \varepsilon_{21} & -\dfrac{1}{\cos\theta_W} + \varepsilon_{22} & \varepsilon_{23} \\ -\dfrac{\tan\theta_W}{\sqrt{\cos 2\theta_W}} + \varepsilon_{31} & \dfrac{\sin\theta_W \tan\theta_W}{\sqrt{\cos 2\theta_W}} + \varepsilon_{32} & \dfrac{\cos\theta_W}{\sqrt{\cos 2\theta_W}} \end{pmatrix} \begin{pmatrix} eJ^\mu_{em} \\ gJ^{3\mu}_L \\ gJ^{3\mu}_R \end{pmatrix} \qquad \text{(B.3)}
$$

with ε's defined by

$$
\varepsilon_{21} = -\frac{\tan\theta_W}{\cos^2\theta_W}\left(\tan^2\theta_W \frac{M_L^2}{M_R^2} - \frac{3m_F^2}{M_R^2}\right) , \qquad \text{(B.4a)}
$$

$$\varepsilon_{22} = \frac{\tan^2\theta_W}{\cos\theta_W}\left(\tan^2\theta_W \frac{M_L^2}{M_R^2} - \frac{3m_F^2}{M_R^2}\right) \quad , \tag{B.4b}$$

$$\varepsilon_{23} = \frac{1}{2\cos\theta_W}\left[\frac{\tan^2\theta_W\left(3-2\sin^2\theta_W\right)}{\cos^2\theta_W}\frac{M_L^2}{M_R^2} - \frac{6m_F^2}{M_R^2}\right] \quad , \tag{B.4c}$$

$$\varepsilon_{31} = -\frac{\tan\theta_W\sqrt{\cos 2\theta_W}}{\cos^2\theta_W}\left(\tan^2\theta_W \frac{M_L^2}{M_R^2} - \frac{3m_F^2}{M_R^2}\right) \quad , \tag{B.4d}$$

$$\varepsilon_{32} = \frac{\sqrt{\cos 2\theta_W}}{\cos^3\theta_W}\left(\tan^2\theta_W \frac{M_L^2}{M_R^2} - \frac{3m_F^2}{M_R^2}\right) \quad . \tag{B.4e}$$

Hence, the axial vector coupling constant of the physical Z boson to charged leptons is given by

$$g_A^l = \frac{1}{2} + \frac{3\sin^2\theta_W - 4\sin^4\theta_W}{4\cos^4\theta_W}\frac{M_L^2}{M_R^2} - \frac{3m_F^2}{2M_R^2}\left(1 - \frac{\sin^2\theta_W}{\cos^2\theta_W}\right) \quad . \tag{B.5}$$

In the estimation Eq.(4.4) the following values of parameters are used.

$$m_F = 46\ \text{GeV} \quad , \tag{B.6a}$$

$$M_L = M_W = 80.22\ \text{GeV} \quad , \tag{B.6b}$$

$$\sin^2\theta_W = 0.2318 \quad . \tag{B.6c}$$

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Table I . Quantum numbers of the preons.

Preon	$SU(N_{HC})_{HC} \times SU(3)_C \times U(1)_{em}$ representation
F^U	(N_{HC} , **1** , 1/2)
F^D	(N_{HC} , **1** , -1/2)
$C^{(i)}$	(N_{HC} , $\mathbf{3}^*$, -1/6)
$S^{(i)}$	(N_{HC} , **1** , 1/2)

Table II . Quantum numbers of the preons.

Preon	$SU(2)_L \times SU(2)_R \times U(1)_B \times U(1)_L$ representation
$\begin{pmatrix} F^U \\ F^D \end{pmatrix}_L$	(**2** , **1** , 0 , 0)
$\begin{pmatrix} F^U \\ F^D \end{pmatrix}_R$	(**1** , **2** , 0 , 0)
$C^{(i)}$	(**1** , **1** , -1/3 , 0)
$S^{(i)}$	(**1** , **1** , 0 , -1)

Table III . Tentative values of our model parameters; Λ, N_{HC} and m_F .

$m_F = 46\text{GeV}$

$\Lambda[GeV]$	10^4	10^6	10^{19}
N_{HC}	73	46	13

$m_F = 1\text{GeV}$

$\Lambda[GeV]$	10^4	10^6	10^{19}
N_{HC}	49	35	12

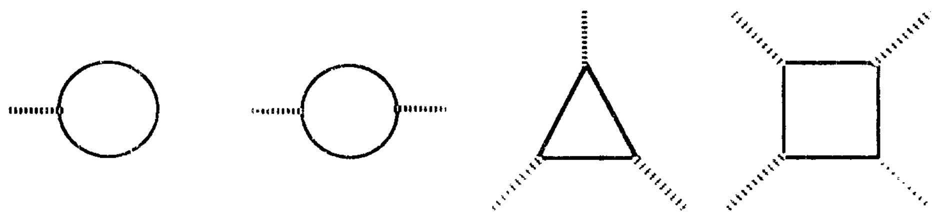

Fig.1. Preon loop diagrams.

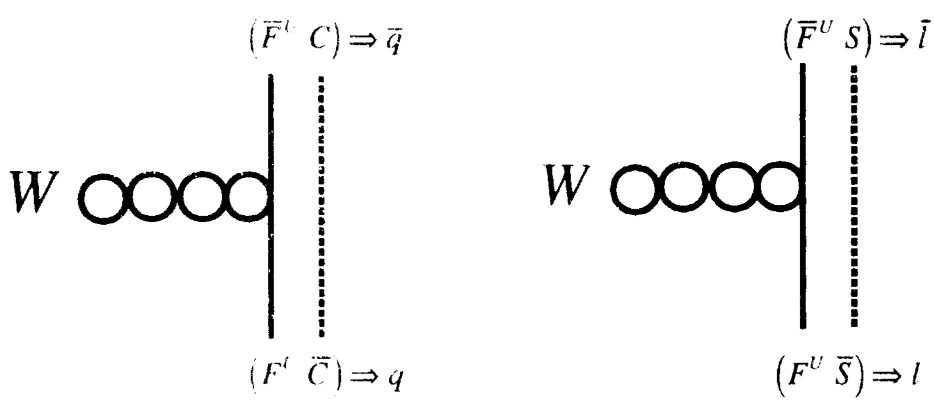

Fig.2. Weak bosons interacting with composite quarks and leptons.